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CURRENT METHODS OF VEGETATION AND SOIL MONITORING

REPORT TO BLM

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1. INTRODUCTION

Monitoring is necessary to determine the effects of management actions on the status of resources and is a crucial part of the adaptive management cycle. Land management decisions always have some impact and should be monitored for either short- or long-term, positive or negative effects on resources.

Emergency Stabilization and Burned Area Rehabilitation (ES&R) treatments are short-term, high intensity treatments designed to mitigate the adverse effects of wildfire on public lands. Monitoring to determine effectiveness of ES&R and BAER treatments is often conducted, but the overall success of these actions is still unknown (Robichaud et al. 2000, Pyke and McArthur 2002, GAO 2003).

The purpose of monitoring ES&R treatments is to determine whether or not they are effective at meeting the objectives of post-fire stabilization and rehabilitation. The overall objective of the Bureau of Land Management's (BLM) ES&R program is "to stabilize and prevent unacceptable degradation to natural and cultural resources, to minimize threats to life or property resulting from the effects of a fire, or to repair/replace/construct physical improvements necessary to prevent degradation of land or resources." (BLM Handbook H-1742-1). Other, more specific objectives may be included depending on the land management unit and approved land use planning documents. According to the BLM Handbook H-1742-1, monitoring of ES&R projects to determine if objectives are being met is encouraged. The objectives of the United States Forest Service (USFS) Burned Area Emergency Response (BAER) program are to minimize damage to watersheds by wildfire. Damage may include loss of soil productivity, deterioration of water quality, and threats to human life and property (Forest Service Handbook FSH 2509.13). The Forest Service Handbook (FSH 2509.13) states that evaluations of BAER projects may be conducted to determine if a project is performing as desired. Both agency publications (BLM Handbook H-1742-1 and FSH 2509.13) encourage but do not require monitoring.

Currently, there are no standard vegetation or erosion monitoring protocols used by the BLM or USFS to assess the effectiveness of ES&R and BAER treatments (Pyke and McArthur 2002, GAO-03-430 2003, Robichaud et al. 2000). In a review of both the BLM and USFS emergency fire rehabilitation and stabilization programs, GAO (2003) stated "most land units do not routinely document monitoring results, use comparable monitoring procedures, collect comparable data, or report monitoring results to the agencies' regional or national offices". Reviews by Robichaud et al. (2000) and GAO (2003) found that little monitoring had been done and that existing data from monitoring and research was insufficient to evaluate treatment effectiveness. The new Department of the Interior manual (620 DM 3, Burned Area Emergency Stabilization and rehabilitation), approved in May 2004, states that monitoring must be "implemented to ensure that treatments and activities are properly implemented, effective, and maintained." A number of manuals have been written for personnel in the USDA and USDI that describe how to design monitoring programs and detail specific monitoring protocols and when they should be used.

The purpose of this report is to 1) describe current methods for vegetation and soil monitoring documented in agency manuals and available for use by USDI and USDA personnel, 2) determine what methods are generally used in the field, and 3) propose potential standardized techniques to determine the effectiveness of ES&R treatments for attaining program objectives over a large geographic area.

2. METHODS

Vegetation and soil monitoring manuals produced by USDA, USDI, and Department of Defense (DOD), were reviewed. Only procedures that could be used to assess post-fire rehabilitation or stabilization treatment effectiveness in arid and semi-arid rangelands within the intermountain west were reviewed.

Because it is impractical to contact all offices to get a comprehensive view of what techniques are most commonly used, managers were contacted and either provided contacts for their area or examples of monitoring reports outlining typical methods employed for post-fire stabilization or rehabilitation monitoring.

To determine what techniques BLM field offices used, we talked to personnel typically involved in collecting monitoring data on ES&R projects or in charge of personnel collecting these data in nearly all states with the semi-arid shrub grassland ecosystems that have had recent projects with monitoring. In many instances, field office personnel provided us with either written protocols describing techniques that they used, or monitoring reports that described methods used to collect data on specific projects. Data were not obtained from all offices because fires were rare or absent from the areas managed by some field offices.

Protocols used by the BLM offices or during projects were tallied to derive an estimate of how often a particular technique was used. In instances where monitoring was conducted by researchers, these techniques were included in overall tallies. Some offices did not have written protocols, did no monitoring, or did not respond to requests.

For the USFS, several offices in each region (2,4,5, and 6) were contacted and provided typical methods used for monitoring ES&R projects. The USFS often receives aid with monitoring BAER projects through either research labs, collaboration with universities, or contracting with private corporations. Therefore, several researchers were contacted to determine the methods they used during research/or monitoring of BAER and ES&R monitoring.

To determine current methods used by the United States Fish and Wildlife Service (USFWS) and Bureau of Indian Affairs (BIA), and National Park Service (NPS), the regional ES&R leaders were contacted.

3. VEGETATION AND SOIL MONITORING

The following manuals are currently used as references by agencies to conduct vegetation and soils monitoring. There are many similarities between techniques in these handbooks. Manuals vary in how much they ask the user to adhere to the exact procedures described. None of these procedures or sampling techniques is mandatory and personnel are allowed to use other procedures to meet their particular monitoring needs.

The eight monitoring manuals described below have different goals. Three of them, the Fire Monitoring Handbook (FMH) from the NPS, the Fire Effects Monitoring and Inventory Protocol (FIREMON) from the USFS Missoula Fire Lab, and the Fuel and Fire Effects Monitoring Guide from the USFWS are focused mainly on pre- and post fire monitoring (i.e. prescribed fire). Three manuals provide techniques for monitoring changes in condition of land over time or in response to management actions. These are Sampling Vegetation Attributes (BLM), Land Condition Trend Analysis (LCTA) from the Department of Defense, and Monitoring Manual for Grassland, Shrubland, and Savanna Ecosystems from the Agricultural research service (ARS).One manual specifically addresses the problems of monitoring individual plant species (Measuring and Monitoring Plant Populations), and one specifically addresses soil quality monitoring techniques (Soil Quality Monitoring Methods). These manuals present monitoring methods that have been commonly used for decades with slight variations in protocols. In addition, they address issues associated with developing monitoring programs such as developing measurable objectives, monitoring program design such as stratification into meaningful monitoring units, sample adequacy, and statistical analysis.

Many of the strategies and techniques are similar among manuals (Table 1). In all of the manuals, discretion is given to the monitoring program coordinator to modify protocols depending on their particular need. Strengths and weakness of some of these general methods are given in tables A-1 and A-2. The NPS Fire Monitoring Handbook, USFWS Fuel and Fire Effects

Monitoring Guide, and FIREMON are intended to perform in a wide variety of ecosystems, hence the flexibility in protocols, while the ARS publication and the BLM's Sampling Vegetation Attributes are for more specific ecosystems (shrublands, grasslands, and savannahs).

Table 1. General subjects and methods discussed in the eight different monitoring manuals. Acronyms are as follows: FMH = Fire Monitoring Handbook, SVA = Sampling Vegetation Attributes, MMGSS = Monitoring Manual for Grassland, Shrubland, and Savannah, FIREMON = Fire Effects Monitoring and Inventory Protocol, FFEMG = Fuel and Fire Effects Monitoring Guide, MMPP = Measuring and Monitoring Plant Populations, LCTA II = Land Condition Trend Analysis II, and SQMM = Soil Quality Monitoring Methods. Key area refers to a study location that is chosen to represent a larger area.

SUBJECTS	NPS FMH	BLM SVA	ARS MMGSS	USFS FIREMON	USFWS FFEMG	BLM MMPP	DOD LCTA II	USFS SQMM
Objectives	x	x	x	x	x	x	x	
Stratification	x	Key	x	x	x	x	x	
Control/Reference	x	x	x			x		
Random Sampling	x	x	x	x	x	x		
Sample Adequacy	x	x	x	x	x	x	x	
Statistical Analysis	x	x	x	x	x	x	x	
METHODS								
Photo Points	x	x	x	x	x	x	x	
Cover Estimation		x		x	x	x	x	
Line Intercept		x		x	x	x	x	
Point Intercept	x	x	x	x	x	x	x	
Frequency		x			x	x	x	
Density	x	x	x	x	x	x	x	
Gap Intercept			x					
Soil Stability			x					
Compaction			x					
Production		x			x	x	x	
Structure		x	x		x		x	
Erosion Bridge					x			x
Erosion Pins								x
Erosion Trough								x
Silt Fence								x

3.1 Fire Monitoring Handbook (NPS)

The NPS fire monitoring handbook (FMH) is designed for monitoring the effects of prescribed fires. The handbook is composed of sections that lead the reader through the entire monitoring process including developing objectives, program design, vegetation monitoring protocols, and data analysis.

The fire monitoring handbook describes how to formulate specific objectives. Objectives are broken down into management objectives and monitoring objectives. Management objectives include 1) identifying the target populations, 2) delineating the time frame for change, 3) defining the amount and direction of desired change or target/threshold condition, and 4) determining which variables to measure. Monitoring objectives are more specific than management

objectives and include statements about goals for change or thresholds to be met. Monitoring objectives include specific statements regarding the minimum detectable change desired, level of power, and the alpha level that sampling will achieve.

Four levels of monitoring are discussed in the FMH system. Each level of monitoring has a set of recommended standard (RS) variables that are collected. In the case of wildfire, a limited set of variables are monitored (level I and II). Level I and II variables are restricted to environmental and fire observation monitoring and are conducted for all fires, wild or prescribed. In addition to level I and II variables, level III and IV variables may be monitored on prescribed fires. Level III variables include photographs, cover, density, and fuel measurements. Level IV variables are level III variables that are monitored on a long term basis. In the case of prescribed fire, plots are established before the burn and vegetation attributes are measured pre-and post fire.

The Fire Monitoring Handbook also describes how to delineate monitoring types. Monitoring types are defined as land areas with relatively homogeneous major fuel-vegetation complexes or vegetation associations. Additional variables may include vegetation composition and structure, sensitive species, physiography, fuel characteristics, burn prescriptions, or management types. Selection criteria are established for each monitoring type which allow for rejection of randomly placed plots that are anomalous to the defined monitoring type. Within each monitoring type a pilot study is conducted which involves randomly placing ten macroplots. An estimate of the minimum sample size is calculated from the initial ten macroplots using the attribute with the highest variability.

The NPS Fire Monitoring Handbook uses macroplots that are 20 m x 50 m within which all other measurements are taken. There are three plot types that can be used; grassland, brush, and forest plots. The NPS fire monitoring handbook has spawned two associated databases. The first, called FMH after the fire monitoring handbook is a DOS-based system that is currently being phased out in favor of a new system called Fire Effects Analysis Tool (FEAT). The Fire Effects Analysis Tool is a Microsoft Access-based database that has the ability to link to spatially explicit GIS data. This database may eventually be merged with the FIREMON database and converted to a more powerful database system.

Within macroplots, 30- or 50- m point intercept transects are established. Along each transect a ¼ inch diameter rod is dropped every 30 cm (100 or 166 point intercepts). At each point, each species that touches the rod is recorded. Multiple canopy layers are sampled using this method. If the rod does not touch a basal portion of a species the substrate intercepted by the sampling rod is recorded. Vegetation over 2 m high is not recorded. Height measurements can also be taken at each point to assist in describing wildlife habitat. Detailed directions are given on how to assign proper plant codes to all species according the USDA PLANTS database.

Shrub density is recorded in a belt transect adjacent to the point intercept line. The width of the belt may be variable but each individual is counted which has > 50% of its rooted base within the belt. The species, age class (immature-seedling, resprout, or mature-adult), and status of each plant is recorded (alive or dead) for each individual within the belt.

For density of herbaceous layer species, a quadrat is placed at intervals along the shrub density transect. The size of the quadrat used in the handbook is a 0.25 x 4 m (1 m^2), however this size can be adjusted depending on the size, density, and spacing of the species being counted. Each individual that has > 50% of its rooted base within the quadrat is counted and survival status (living or dead) is noted. Frequency is discussed in the general methods section of the handbook, but is not included in any of the sampling protocols. Accuracy standards required for all density measurements are set at ± 5%.

If trees are measured, all overstory trees >15 cm diameter at breast height (DBH) within the macroplot are tagged and measured. Detailed instructions are given on how the measurement of DBH should be conducted. Optional measurements include descriptions of crown position for live

or dead trees (dominant, co-dominant, intermediate, subcanopy, or isolated). Damage codes can also be used to document damage or disease to overstory trees. Pole sized and seedling trees (<15 cm DBH) can also be counted and measured within the macroplot.

The analysis portion of the handbook describes concepts used for data analysis such as data summarization, variability, minimum detectable change, and other general statistical concepts. There is also a discussion on how to evaluate data with regard to the objectives.

3.2 Sampling Vegetation Attributes (BLM)

The purpose of the interagency manual Sampling Vegetation Attributes (BLM 1734-4) is to "provide the basis for consistent, uniform, and standard vegetation attribute sampling that is economical, repeatable, statistically reliable, and technically adequate." The authors note that the methods included in BLM 1734-4 are the primary sampling methods used in the western United States.

The introduction of Sampling Vegetation Attributes briefly discusses general considerations of monitoring such as location of study sites, key areas and species, and reference areas. The third chapter discusses study design and analysis and includes sections on planning the study and statistical considerations. Some planning elements discussed include identifying objectives and three types of study designs (baseline, macroplot, and linear). The section on statistical considerations initially discusses target populations then proceeds with typical statistical elements of monitoring including sampling, types of error, confidence intervals, quadrat size and shape, interspersion, pilot studies, sample size determination, and graphical display of data. For a detailed explanation of sample adequacy it refers the reader to Measuring and Monitoring Plant Populations (BLM 1730-1). There is also a chapter describing each vegetation attribute and the advantages and limitations of each (frequency, cover, density, production, structure, and composition). The rest of the manual is dedicated to describing the methods. The manual recommends establishing a photopoint (close-up and general views) at all study sites where methods are used. Included in the manual are datasheets that can be used to record data while using the methods described and to document the study location and data collected at each site.

Sampling Vegetation Attributes describes several methods used to measure vegetation frequency including pace frequency, single and nested quadrat frequency, and cover/frequency methods. For the single quadrat method, the presence or absence of each species is noted within several quadrats located along a transect. The overall frequency is then tallied at the end of the transect. For nested frequency, several sub-quadrats are included within a larger quadrat and the presence or absence of each species is noted in each quadrat size. The collection of frequency data is highly dependent upon quadrat size. For instance, very low density species will be rarely sampled in small quadrats while very high density species will be encountered in close to 100% of large quadrats. Frequencies close to 0% or 100% do not allow change detection to occur in subsequent sampling sessions. For this reason, nested quadrats that provide intermediate frequencies (between 30% and 70%) are more often used.

The cover frequency method involves collecting single or nested frequency data as described above, but also includes recording cover points at the corners or tines of each quadrat. Pace frequency involves pacing out a temporary transect and collecting frequency data at the tip of the boot every certain number of paces.

The dry weight rank method is also included in sampling vegetation attributes. This method involves ranking the three species that the observer visually estimates to contribute the largest amounts of biomass within each quadrat. The proper sized quadrat is selected based upon the number of species that occur in the plots. At least three species need to occur in every plot. Composition by biomass is assumed to be 70%, 20% and 10% for the species with the rank of 1, 2, and 3, respectively.

Several techniques are used to estimate or measure cover. The canopy cover estimation method is based on Daubenmire (1959). A 20- x 50-cm quadrat is used to estimate canopy cover of each species within the quadrat. Each species' canopy cover is visually estimated and divided into six cover classes (0-5, 5-25, 25-50, 50-75, 75-95, and 95-100%). The mid-points of each category are used to calculate cover for each species. Frequency and composition data can be derived from the canopy data.

Line intercept is a method for measuring canopy or basal cover. This method is particularly useful for shrubs and perennial grasses with relatively dense canopies. Line intercept is not suited for measuring cover of annual forbs or grasses, or rhizomatous species. Canopy and/or basal cover and composition are collected along a transect line. The linear length of interception of each shrub or perennial grass along the transect is recorded. Both cover and species composition data are derived using this method.

The point intercept method uses sighting devices, pins, pin frames, or point frames to sample points along a transect. At each point, whether a single pin representing a point or a pin frame, the plants or substrate intercepted by the sampling pin or pins are recorded. If no plants are intercepted there are four types of ground-level hits (litter, bare ground, gravel, and stone). Using this method, ground cover, basal cover, and canopy cover can be estimated.

Density involves counting individuals of plant species within quadrats along transects, or within large belt transects to estimate the number of individuals per acre or hectare. The manual notes that size and shape of the quadrats are important depending on the species of interest. For example, rectangular quadrats usually capture more variation, reducing the number of sub-samples (quadrats) required. Also, if you are estimating the density of a small species (such as an annual grass) then using a large quadrat will take a long time. It is best to use a quadrat size and shape which is suitable for plants of interest.

Two additional techniques described in BLM 1734-4, the cover board and the Robel pole are used to track changes in vertical vegetation structure over time. The cover board consists of a board painted with alternating light and dark segments that is placed vertically at a point of interest along a transect or within a plot. The observer stands 15 feet away from the board and estimates the percent cover of vegetation within each segment using Daubenmire cover classes. The Robel pole is similar to the cover board method except that height classes are used instead of vegetation cover. The pole is painted with alternating segments of one inch lengths and the vegetation height at each point is placed into the appropriate class.

3.3 Monitoring Manual for Grassland, Shrubland, and Savannah (ARS)

The Monitoring Manual for Grassland, Shrubland, and Savannah describes techniques suitable for measuring three key rangeland health attributes; soil and site stability, hydrologic function, and biotic integrity. The manual is separated into two volumes (Volume I: Quick start and Volume II: Design, supplementary methods and interpretation). Volume 1 contains a short introduction to designing a monitoring program and describes six primary monitoring techniques. Volume 2 contains a more in-depth review of the issues associated with designing a monitoring program as well as secondary monitoring techniques that may be used depending on management objectives. Volume 2 also includes information on how to interpret data collected using these methods.

This publication describes several levels of monitoring intensity based upon objectives and resources. These levels are 1) qualitative documentation of large changes in vegetation structure, 2) semi-quantitative documentation of changes in vegetation composition, structure and soil stability, 3) quantitative documentation of changes in vegetation composition, structure and soil stability, and 4) quantitative documentation of changes in the status of specific issues (e.g. compaction, water infiltration, vegetation production or streambank stability). There are also three options for determining how many measurements to take. Option one uses general

recommendations from data taken at arid and semiarid grasslands. These are based on studies done by the authors in New Mexico in eight different community types. Option two uses specific results from the eight plant communities to determine sample size (depending on which community best matches the community you are sampling). Option three uses sample adequacy equations to determine the number of measurements required.

An important step when using this method is landscape stratification. This is similar to the monitoring types used in the NPS Fire Monitoring Handbook. This is accomplished by following a three step process: 1) collect background material such as maps and aerial photographs; 2) define the stratification criteria (topography, vegetation, management actions); and 3) divide the area into soil-landscape-vegetation units that fit the stratification criteria.

The macroplot used in the Monitoring Manual for Grassland, Shrubland, and Savannah is a circular area with a radius of 55 m. The plot contains three 50-meter transects radiating at 120° angles that begin 5 m from the central point. This layout is similar to designs used by two common national inventory techniques, Natural Resources Inventory on private rangelands (Spaeth et al. 2003) by the Natural Resources Conservation Service and the Forest Inventory Analysis of forest health (USFS Forest Service 2003). All vegetation and soil sampling methods are conducted along these three transects. The six primary methods used in this manual are photos, line-point intercept, canopy/basal gap intercept, a soil stability test, and a density belt transect. The line-point intercept and density belt techniques are comparable to other forms of this method. The canopy and basal gap measurements are similar to line intercept methods where gaps in vegetation are recorded instead of the vegetation itself. This is used to measure potential for erosion and weed invasion. The soil stability test involves taking a small sample of surface or subsurface soil and dipping it in water to determine how rapidly it dissipates and was originally described in the ARS publication Soil Quality Test Kit.

These techniques represent those variables most closely associated with site stability. Other methods from volume II include tree density and vegetation structure. Other procedures contained in the manual but not described here include a soil penetration resistance test, soil water infiltration test, plant production, and riparian vegetation monitoring.

The line-point intercept technique is essentially the same technique as that described in Sampling Vegetation Attributes, the NPS Fire Monitoring Handbook, and FIREMON. A transect is established according to the layout described above and a measuring tape is stretched along it. A rod less than 1 mm in diameter is lowered each meter along the transect from a standard height. At each point, the species that intercepts the rod is recorded. Intercepts are separated into top canopy, lower canopy (including basal hits) and soil surface. Soil Surface hits may include rock, litter, duff, moss, lichen and unprotected soil. Using this method, percent canopy cover, basal cover, and percent bare ground can be calculated.

The canopy and basal gap intercept method measures the proportion of a transect that is covered by large gaps in vegetation cover. Large gaps are indicators of potential soil erosion and weed invasion. The method involves stretching a tape along a transect and recording canopy or basal gaps that are greater than 20 cm. Using this technique, the percentage of the line covered in large gaps can be calculated and quantified by size class (larger gaps lead to higher erosion potential). The percentage of line covered by gaps can be correlated to different stable states (Herrick et al. 2002).

A belt transect is used to measure density of woody shrubs or perennial herbaceous plants for species that have less than 5% cover. For smaller plants, such as exotic annual forbs, a smaller quadrat can be placed at regular intervals along each transect to estimate their density. This method involves counting plants that are rooted within the belt. The belt may be between 1 and 6 meters wide by 50 meters long (depending on the density, lower densities will require larger belt transects). Additionally, plants are recorded into appropriate size classes.

The method for determining tree density is derived from the USFS FIA National Core field guide (USDA Forest Service 2003). First, size classes are determined (DBH) that are of interest. Second, four 7.3 meter radius plots are established, one at each end of the three transects and one in the middle. The species, height, and DBH of each tree are recorded.
The vegetation structure method uses a visual obstruction measurement similar to that used with Robel pole, cover board, vegetation profile board, and density board techniques. A sighting pole with bands of alternating colors is located along the transect. The observer stands 5 m away and records a 0 (unobstructed) or 1 (obstructed) for each band on the sighting pole. From this technique, the percent visual obstruction can be calculated as well as the foliage height diversity.

This manual includes two procedures which measure how susceptible a site is to erosion. The first procedure is the soil stability test. This test provides information about the degree of soil structural development and erosion resistance. It involves collecting small samples of surface and subsurface soil. After the samples are dry, they are placed in a small sieve which is then lowered into de-ionized water. The time the sample takes to dissipate along with additional immersions are used to assign a stability class to the sample. Surface and subsurface soils in higher stability classes have less susceptibility to erosion. This test is used in conjunction with vegetation cover and gap intercept to determine the risk of exposed soil to water erosion.

The second method is channel/gully profiles. This method involves establishing two permanent rebar posts on either side of a channel or gully. At specified intervals along a tape stretched between the two posts the distance between the tape and the soil surface is recorded. This method can monitor changes in the channel profile such as bank angle and the channel width. From this information the width-to-depth ratio can be monitored over time.

3.4 Fire Effects Monitoring and Inventory Protocol (USFS)

The Fire Effects Monitoring and Inventory Protocol (FIREMON) is a fire effects monitoring and inventory system that includes vegetation sampling protocols, a Microsoft Access database, and a landscape scale assessment to quantify fire effects. This includes monitoring fuel and vegetation attributes. To design a monitoring program, FIREMON uses an integrated sampling strategy that involves developing objectives and determining sampling resources. First, objectives of the monitoring program are formulated. The FIREMON manual encourages objectives that are specific, measurable, achievable, relevant, and time based.

Once objectives are known, the sample area is stratified into homogeneous units similar to monitoring types or strata, resulting in a set of potential polygons to sample. The available resources for sampling are calculated and compared to the number of polygons, resulting in the recommended sampling approach. There are two main sampling approaches, relevé (qualitative) and statistical. The relevé method is applied when there are clearly not enough resources to sample in a way that would be adequate for a statistical analysis. This method is used mainly as a descriptive method or inventory. The statistical method is used when there are enough resources to sample in a statistically adequate way. The authors recommend three potential sampling intensities (simple, alternative, and detailed). The simple sampling scheme is used when the number of plots that can be established is one half or less than the number of plots needed. The alternative sampling scheme generally use the relevé approach to describe all the important conditions that need to be monitored and a statistical approach is not warranted. The detailed sampling intensity generally uses the statistical approach. The goal of the detailed sampling intensity is to sample all polygons.

The first step in any of these sampling intensities is sample size determination. The level of sampling intensity is determined by comparing the number of plots required to the number of plots that can be possibly sampled given the sampling resources. Only the alternative and detailed sampling intensities can result in a statistically valid sample. The authors suggest that anytime a statistical approach is taken to consult with a professional statistician.

Once the sampling approach is determined and plot locations decided upon, the user chooses which techniques to use at each plot. All data collected at a particular site are linked by a plot description form which includes background data as well as geographic location coordinates for each plot. One or several macroplots are established at each stand or stratified sampling unit. At each macroplot, the data of interest are collected. Observers fill out the appropriate datasheets and enter the data into the MS Access database. The techniques in FIREMON are not strict – the user has the option to modify them and the database will accommodate many types of changes. Any changes to the published techniques as well as any information from the monitoring design process (such as objectives or problems encountered) are documented in a section of the database for metadata.

The cover/frequency technique uses a 20 x 20 m macroplot. Five transects are randomly located along and perpendicular to the baseline of the macroplot. At least five quadrats are placed along each transect at specified intervals. In addition, frequency subplots are defined within each cover quadrat. Within each quadrat, the cover class of each species is estimated using the FIREMON cover classes, and species are placed into the proper frequency subplots. This method produces an estimate of the percent cover of each species as well as an estimate of its frequency. Cover classes in FIREMON are the same no matter what attribute is being estimated (0, >0-1, >1-5, in 10% increments until >95-100). Frequency, cover and composition data can be derived from the cover/frequency data.

The density method in FIREMON uses belts and quadrats to estimate vegetation density (similar to the Monitoring Manual for Grassland, Shrubland, and Savannah). A belt transect of 20 m x 1 m for smaller shrubs, or 20 m x 2 m for larger shrubs are delineated within the macroplot. Within each belt transect, the species and size class of each shrub is recorded. For smaller herbaceous species, a 1m x 1m quadrat is recommended at intervals along the belt. Using this method the density of all species present in the macroplot can be estimated.

The point intercept method described in FIREMON is similar to other types of point intercept. The FIREMON methods give the user flexibility to use point frames or grid frames instead of single point intercepts. Five transects are established within the macroplot. At each foot along the transect a sampling pin is lowered and the plant intercepted is recorded. If no plant is intercepted a ground cover code is recorded. Within FIREMON there are 43 potential ground covers codes including basal vegetation hits, rocks, biological crusts, ash, litter, and snow. The plant status and an estimate of the average height of each plant species is recorded at the end of each transect. Using this method the percent cover of plants and ground cover are estimated.

According to FIREMON, the line intercept technique is especially useful for sampling vegetation greater than 1 m tall. It is primarily designed for plant species with dense crowns or large basal areas, and not good for small, single-stemmed, or rhizomatous species. The technique is similar to other line intercept techniques, plant species status, size class, and average height are also estimated. Percent cover of each species is derived from these data.

Included in the appendix of FIREMON is an alternate method for sampling shrub dominated communities. This method involves a larger macroplot (40 m x 60 m). Density of trees is measured within a 6 x 60 belt transect, shrub density is measured along a 2 x 60 belt transect, and shrub and juniper cover is measured using the line intercept method along a 60 meter transect. Herbaceous cover and frequency are measured using quadrats along the 60 meter transect.

3.5 Fuel and Fire Effects Monitoring Guide (USFWS)

The objective of the USFWS fuel and fire effects monitoring guide (FFEMG) is to integrate fuel treatments and fire effects monitoring into refuge management plans. This manual covers issues associated with planning, fuels, wildlife habitat, water, soil, and air. The planning section covers

project monitoring, monitoring design and analysis, and reporting. This section notes five pitfalls that many monitoring projects encounter. These pitfalls are that 1) projects are never completely implemented, 2) data are collected but never analyzed, 3) data are analyzed but the results are inconclusive, 4) data are analyzed but not presented to decision makers, and 5) data are analyzed and presented but are not used for decision making due to internal or external factors.

Similar to other manuals, the FFEMG describes how to develop management and sampling objectives. It also recommends writing a monitoring plan which describes why monitoring is being conducted, what methodologies will be used, and how results will be communicated. A monitoring plan increases the successful completion of proposed monitoring projects.

The techniques described in the Fuel and Fire Effects Monitoring Guide are derived directly from the BLM's Sampling Vegetation Attributes. These include pace frequency, single and nested quadrat frequency, dry weight rank, Daubenmire cover, line intercept, point intercept, and vegetation structure (cover board and Robel pole).

3.6 Measuring and Monitoring Plant Populations (BLM)

This publication specifically addresses monitoring of single species plant populations but many of the techniques are applicable to general vegetation monitoring. The manual is less of a monitoring system and more of a reference for what factors to consider when designing an implementing a monitoring program.

Measuring and Monitoring Plant Populations begins with addressing the role of monitoring in the adaptive management cycle. The manual emphasizes the use of objectives to describe the desired condition and monitoring to measure the current condition. The manual gives an overview of the monitoring process, setting priorities and scale, and management objectives. It also contains the most complete sections on the principles of sampling, sample adequacy, and statistical analysis of any of the manuals. Several of the other vegetation monitoring manuals refer to this publication when discussing statistics.

This manual does not specify a monitoring program, but describes in general what factors to consider and how to perform various techniques. The manual covers the standard attributes of cover, density, and frequency as well as some qualitative techniques, photographic monitoring and in the case of rare plants, population counts and demographic monitoring.

Measuring and Monitoring Plant Populations covers general aspects of density, cover, and frequency techniques. This includes the uses, advantages, and disadvantages of each attribute and issues associated with each. For density, the manual covers both quadrat and distance methods in general and discusses defining the counting units and boundary decisions. For frequency, the manual also discusses boundary decisions, plot size and shape, stage classes, and arrangements of plots. For cover, the manual discusses the advantages and disadvantages of visual estimation, line intercept, and point intercept and compares and contrasts these methods.

3.7 LCTA II Technical Reference Manual (DOD)

The Land Condition Trend Analysis II (LCTA II) manual developed by the Department of Defense describes issues associated with developing a monitoring program. It introduces the reader to resource monitoring, sampling, and describes vegetation attributes that can be measured. It also describes methods used to measure each attribute. The LCTA was originally a prescriptive manual, but as the program progressed, different methodologies were found to work better at installations that were in different ecoregions, and specific methods were no longer mandated.

The plot designs described in the manual are baseline, macroplot, or linear. The primary methods described in the manual measure vegetation frequency, cover, density, and biomass. The LCTA II describes each method, its applicability, advantages and limitations, equipment,

training, how to establish studies and plot layout (in general terms), the sampling process, and data summary and analysis.

The LCTA II describes methods that are previously discussed in other manuals. These include frequency (single quadrat and nested frequency), cover (line intercept and point intercept), and vegetation structure (cover board and Robel pole). The LCTA II also covers quadrat density but also mentions plotless methods for estimating density such as closest individual, nearest neighbor, random pairs, point-center-quarter, and wandering quarter.

The LCTA II describes biomass/production techniques such as harvesting, double weight sampling, dry-weight rank, estimated biomass. It also discusses forest and tree measurements.

There are no soil erosion monitoring techniques discussed in the LCTA II, but there is an extensive discussion on soil erosion equations (Universal Soil Loss Equation or USLE, Revised USLE or RUSLE, Water Erosion Prediction Project or WEPP, and WEQ (Wind Erosion Equation). These can be used to estimate the amount of erosion provided some basic information about each site is known including percent plant cover, ground cover, and average canopy height (cover and management factor).

This manual also includes a Microsoft Access analysis tool that is capable of storing and summarizing LCTA II data.

3.8 Soil Monitoring Methods (Intermountain Region USFS)

This manual covers several standard methods for measuring erosion. Methods discussed include erosion bridges, erosion pins, erosion troughs, fabric dams, soil ground cover measurements, and photopoints as well as the advantages and disadvantages of each method. It also describes how to use USLE and WEPP to predict soil erosion.

The erosion bridge technique involves placing two rods in the soil and running a level between the two. Then a measuring rod is lowered at several points along the level to the soil surface and the distance measured. Measurements are taken over time to determine if any soil has eroded or been deposited at the site.

Erosion pins can also be used to measure erosion. There are several variations but basically a nail is driven into the ground and the distance between the nail head and soil surface is recorded over time. This method is inexpensive but there can be some problems with the nails becoming dislodged during the study.

Erosion troughs are used to measure the amount of sediment that accumulates over time. A trench approximately 3 feet long and 10 inches deep is dug in the slope and a metal trough is placed inside. Periodically, observers scoop and measure the amount of sediment in the trough in response to rainfall.

Fabric dams trap sediment from a defined area. This technique involves placing several posts or stakes and attaching silt fence to them. The fence traps sediments as water flows through it during rainfall events. The sediment is collected after storm events to provide an estimate of soil loss. This method, originally described by Dissmeyer (1982) has been improved upon and described in greater detail by Robichaud and Brown (2002) including exact specifications and examples of how to perform statistical analyses. Since this method is a direct measurement of erosion it is often preferable to indirect measurements such as those with erosion pins or troughs.

4. NATIONAL MONITORING SYSTEMS

4.1 National Resources Inventory (NRI)

The National Resources Inventory is conducted by the NRCS in conjunction with the Iowa State University Statistical Laboratory. The NRI uses a stratified, two stage sampling method to select sampling units on private land across the nation. At each sampling unit data are collected according to standard protocols resulting in scientifically credible information on the status of natural resources on these lands.

The monitoring methods that are used for NRI surveys on private rangelands include methods previous described in the Monitoring Manual for Grassland, Shrubland, and Savannah. These are line point intercept, canopy and basal gap measurements, soil stability tests, and cover pole.

4.2 Forest Inventory and Analysis (FIA)

The Forest Inventory and Analysis is a census of the nations forest resources conducted by the USFS. There are certain core methods which are consistent across all regions. Regions must follow the core methods but may include additional methods. The FIA consists of three phases of differing spatial scales. Phase one includes remote sensing and satellite imagery to classify forested and non-forested areas. Phase two includes field data collection plots located approximately every 6000 acres, 10% of which are visited each year. Phase three consists of subsample of phase two plots of which 20% are sampled each year and attributes specifically related to forest health are measured. Data collected through the FIA program are available to the public.

General data collected for phase two FIA plots include characteristics such as location information, condition class, forest type, regeneration status, and tree density. Within each phase 2/3 plot, there are subplots, and microplots. Within each subplot extensive tree data are collected (size, age, density, mortality, disease etc). Microplots are located within subplots and are used to collect seedling data.

5. CURRENT METHODS USED BY USDI AND USDA

The Bureau of Land Management (BLM) and the Forest Service (USFS) are the two agencies that spend the most money on ES&R and BAER funds (GAO 2003). The three other DOI agencies (NPS, USFWS, and BIA) involved in BAER and ES&R activities spend far less combined than either BLM or USFS. According to the National Fire Plan Operation and Reporting System (NFPORS), for the fiscal year 2004, USFS planned a total of 1071 activities while all five DOI agencies planned 703 activities. In addition, USFS spent $94 million (planned direct costs) compared to USDI which spent only $36 million (planned direct costs) (NFPORS). This is not surprising in that the most devastating fires occurred in forested lands and often require more extensive treatments and management to protect life and property than do fires on non-forested USDI lands.

Within the USDI, the BLM has the most ES&R and BAER activities of all the agencies. For the 2004 fiscal year, BLM planned 423 BAER and ES&R activities, BIA planned 154, FWS planned 75, and NPS planned 51 (NFPORS).

5.1 Bureau of Land Management

The overall objectives of the BLM ES&R program "is to minimize threats to life or property and stabilize and prevent unacceptable degradation to natural and cultural resources resulting from the effects of fire, in a cost-effective and expeditious manner. The purpose is either to emulate historical or pre-fire ecosystem structure, function, diversity, and dynamics consistent with approved land management plans, or if that is infeasible, then to establish a healthy, stable ecosystem in which native species are well represented." (BLM Handbook 1742-1). The ES&R program is separated into 1) emergency stabilization and 2) rehabilitation. Emergency stabilization is defined as "planned actions to stabilize and prevent unacceptable degradation to natural and cultural resources, to minimize threats to life and property resulting from the effects of a fire, or to repair/replace or construct physical improvements necessary to prevent degradation of land or resources." Emergency stabilization is conducted within one year of the containment of the fire. Rehabilitation is defined as "efforts undertaken within three years of containment of a wildland fire to repair or improve fire-damaged lands unlikely to recover naturally to management approved conditions, or to repair or replace minor facilities damaged by fire."

The BLM currently has no national or state-wide protocols for monitoring post-fire treatment effectiveness. A new revision of BLM handbook 1742-1 (Emergency Stabilization and Rehabilitation Handbook) requires that a monitoring plan be developed. The monitoring plan must describe what monitoring techniques will be used and the specific criteria for measuring a successful treatment or activity. The decision about what monitoring method to use is made at the individual district or field offices. Within these offices, the extent and type of monitoring may vary by the personnel assigned to do the tasks or by the particular ES&R project.

In addition to various types of monitoring methods, there is no standard protocol for how to establish monitoring plots within a project, nor how to determine the appropriate number of plots required to achieve an adequate sample. Several offices have general guidelines about the rate of plots across the burned area (e.g. 2 plots per 500 acres of fire). Most often, monitoring plots are located in key areas Which should represent the soils and vegetation in the larger area. Depending on the size of the burn, some stratification may occur, with key areas being monitored within different soil types or plant communities.

Variations in monitoring methods occur for several reasons. Different personnel may approach the problem differently or have preferred techniques that they are comfortable using. Alternatively, field offices may have chosen to maintain techniques that were used historically to maintain consistency with their earlier monitoring data. Funding may determine how much time and personnel are available, and monitoring techniques may be adjusted to cover the required amount of area in less time or with fewer people. Many personnel in the BLM expressed the concern that monitoring is something that should be done more but is limited by money, time and personnel.

BLM personnel and contractors generally use both qualitative and quantitative methods to assess ES&R treatments. Qualitative methods typically involved taking photopoints and descriptive information about the success of the seeding. Quantitative methods generally included collecting plant cover, density, and frequency data. Techniques to measure cover were line intercept (shrub and grass cover only), line point intercept, step point, Daubenmire cover class estimates, and ocular estimates. Density was usually collected within a quadrat or along a length of drill row. Often, density estimates were restricted to seeded species, and usually not collected for annual invasive species. Invasive annual information was collected more often using cover or frequency estimates.

Two methods that are sometimes used by the BLM and are not described in the monitoring manuals are the FREQDENS technique and drill row densities. The FREQDENS technique was developed to monitor initial establishment for rehabilitation projects and greenstrips. This method

is conduced on a key area where a 100 foot baseline transect is located. Five, 50-ft transects are assigned randomly along the baseline within 20 foot segments (0-20, 21-40, 41-60, 61-80, 81-100). These transects extend at a 45° angle from the baseline. Ten nested frequency frames (divided into four subplots) are placed along each transect. Within each frame the nested frequency, density, and point cover (using the four corners of the frame) are recorded. In addition, shrub density is measured using a circular 1/100 acre plot along each transect. The drill row density method involves counting the number of established plants along a certain length of a drill row, located randomly within a plot area.

Thirty-three BLM offices were surveyed to determine what methods they are currently using to monitor fires (Table 2). Overall, cover is the most often used quantitative technique with density being the second most often used.

Table 2. Quantitative vegetation monitoring methods that were used during 2004 by BLM offices (number of offices in parentheses) in California (2), Colorado (4), Idaho (10), Nevada (4), Oregon (4), New Mexico (1), Utah(7), and Washington(1).

Method	No. Offices (of 33)
Line Intercept	11
Point Cover	8
Cover visual estimation	11
Measured Cover	24
Density	13
Frequency	9
FreqDens	3
Drill Row Density	4
Dry Weight Rank	1
Production	1

5.2 United States Forest Service

The objectives of the USFS BAER program are to initiate action promptly for immediate rehabilitation of watersheds following wildfire to minimize the following potential effects such as loss of soil productivity, deterioration of water quality, and threats to human life and property. These effects are defined primarily in terms of soil movement, overland flow and runoff, sedimentation, and mass movement. For this reason, the USFS has focused more on erosion control treatments. Seeding is conducted less often on USFS land than on BLM lands, and often only annual species are used.

There are also no national or regional USFS monitoring protocols to determine the effectiveness of BAER treatments. However, funds for monitoring of BAER projects were not available to the USFS until 1998 (GAO 2003). At the Forest Service, the choice of monitoring techniques is done on a case by case basis depending on the size of the fire and the personnel involved.

Some treatment effectiveness monitoring is done by researchers from regional forest science laboratories rather than personnel at the individual forests. Monitoring accomplished in this manner is often research-oriented and has produced several useful publications and reports. For instance, Robichaud et al. 2000 compiled a database (BAERDAT) of treatments and results of

USFS BAER treatments and attempted to evaluate different types of treatment effectiveness. USFS researchers at the Pacific Southwest Research Station are monitoring a complex of large fires in southern California (region 5) that occurred in 2003 (Cedar, Paradise, Grand Prix/Old, Piru, Padua, and Simi). Monitoring of all these fires is being done to ensure a coordinated monitoring strategy and protocols for this complex of fires. Monitoring of all treatments associated with these fires is being conducted including mulching, channel, road, archaeological, weed, seeding, and T&E species. For erosion control treatments (aerial mulching, hydromulching, and fiber rolls), silt fences were the primary method of monitoring effectiveness. Road treatments and channel treatments were monitored by detailed surveys after implementation and rain events. Vegetation monitoring on seeded sites on this fire complex used the cover/frequency method detailed in FIREMON.
Other, large profile fires have also been the subject of research type monitoring. This includes the Hayman fire in Colorado. Watershed sites and rill monitoring sites were established to determine the effect of applied treatments (aerial hydromulching, dry mulch, hand scarification, and contour felled logs) on run off and erosion. Control areas were also monitored to determine the effects of non-treatment. On this fire, researchers are using silt fences and h-flumes to determine erosion.

Within region 4 (Utah, Nevada, Southern Idaho, and western Wyoming) of the forest service, a region specific supplemental chapter to FSH 2209.21 (Rangeland Ecosystem Analysis and Monitoring Handbook) entitled "Rangeland Trend Monitoring" has been written to specifically address monitoring of rangeland resources. Methods used in this handbook are also used in post-fire treatment effectiveness monitoring. The nested frequency method is most often used for monitoring fire rehabilitation treatments in this region. This method is described as being highly objective, relatively easy to perform, repeatable and reliable, and allows detection of vegetation changes.

Within region 6 (Oregon and Washington) there have only been a few recent fires. For the Eyerly fire on the Deschutes National Forest, silt fences were used to monitor erosion. In addition to measuring build up of sediments behind silt fences, personnel also conducted detailed surveys to try to correlate silt fence results with visual observations of draw-felled trees. Extensive photo and erosion pin data was also collected after the Biscuit fire in the Siskiyou Rogue River National Forest. On this fire, the plots were randomly located and stratified to sample areas within the fire that had a moderate to high burn severity.

5.3 National Park Service

The objectives of the National Park Service ES&R program are the same for the other Department of the Interior agencies as outlined in 620 DM 3. These are to "to stabilize and prevent unacceptable degradation to natural and cultural resources, to minimize threats to life and property resulting from the effects of a fire, or to repair/replace or construct physical improvements necessary to prevent degradation of land or resources." Emergency stabilization is conducted within one year of the containment of the fire. Rehabilitation is "efforts undertaken within three years of containment of a wildland fire to repair or improve fire-damaged lands unlikely to recover naturally to management approved conditions, or to repair or replace minor facilities damaged by fire."

The National Park Service generally follows the procedures laid out in the NPS fire monitoring handbook when determining the effects of prescribed fire. In this handbook, there is no significant post-burn monitoring of cover, density unless the burn was prescribed (level 1 and 2 monitoring). For prescribed burning they are monitoring level 3 and 4 variables which are designed to detect change of plants and soils pre- and post fire (see description above). Several parks conduct their own monitoring programs.

In general post-fire treatments such as seeding or extensive erosion control are seldom applied on National Park Service Lands primarily because the mission of the service is different from that of the BLM or USFS. Mitigation of fire effects is often not necessary as there are no immediate threats to life or property. Extensive post fire monitoring has nevertheless been done on National Parks to document the effects of the fire and to track and eradicate noxious plants. Protocols for monitoring wildfire may be different than the Fire Monitoring Handbook because of the NPS focus on obtaining pre-burn data, which is not possible for wildfires.

5.4 United States Fish and Wildlife Service

The USFWS has the least BAER and ES&R activities of any agency. Monitoring of BAER treatments is also on a case by case basis. In some instances, such as the recent Longstreet fire at Ash Meadows NWR, the USFWS consulted with other agencies (USGS) to develop a monitoring program.

Region 1 of the USFWS is currently working on a fire monitoring manual for the fish and wildlife service. The draft manual uses many of the basic ideas in the NPS fire monitoring handbook. All of the techniques described in previous manuals are used in this handbook. Region 2 of the USFWS is moving toward the FIREMON protocol because of its flexibility.

5.5 Bureau of Indian Affairs

As with most of the other agencies, there is no standard protocol for treatment effectiveness monitoring at the Bureau of Indian Affairs. Treatment monitoring is on a case by case basis.

One of the largest recent fires occurring primarily on BIA administered land was the Rodeo-Chediski fire in Arizona. This fire is being monitored using a research type approach. This fire was stratified into eight separate upland monitoring types. Plots were then randomly located within the stratified areas with a minimum of 5 plots per strata. Macroplots were 20 x 50 m. Within each macroplot, 50 meter transects were established and 1 x 1 m quadrats were placed at each meter along the transect. Within each quadrat the frequency, cover of each species (estimated), bare ground (estimated), and forage usage were recorded. In every fourth quadrat, the density of all species was recorded. Biomass was collected in a subset of all the quadrats.

6. DISCUSSION

There are seven manuals produced by USDA , USDI, and DOD that address the subject of vegetation monitoring. All of the manuals explain methods and strategies associated with measuring the three basic vegetation attributes of density, frequency, and cover (Table 1). These vegetation attributes are also the most commonly measured attributes by federal agencies when monitoring post fire rehabilitation projects. In addition, the manuals generally agree on what subjects should be addressed during monitoring projects (objectives, stratification, controls, random sampling, sample adequacy, and statistical analysis) (Table 1). In addition, there are several resources that describe methods of measuring soil loss. These methods directly address concerns in ES&R objectives and should also be included with vegetation monitoring methods to assess the impacts of ES&R treatments.

There are advantages and disadvantages to measuring each vegetation attribute (cover, density, frequency) (Table A-1). Cover and density are the most commonly measured attributes. There is only one quantitative method to collect density data, counts per unit area, hence it is fairly objective. Other techniques exist that allow for categorized density ranks based on visual estimations, but these are subjective by design and will not be discussed further. For cover, there are three basic methods with point cover being the most objective method (Table A-2). For each method there are factors that can be changed to adjust to the particular sampling situation without changing the basic method. For cover, transect length and number of points per transect can be

changed to capture more variability. For density, quadrat size can be adjusted to fit the community being sampled.

There are four factors that prevent data collected on different projects but found in similar ecosystems from being comparable: 1) different protocols used to collect the same vegetation attributes, or different attributes being collected altogether, 2) different methods of identifying monitoring units (soil-landscape-vegetation unit), 3) random sampling and 4) adequately sampling monitoring units. A standard monitoring strategy that is objective-based could overcome these obstacles and enable the BLM to compare data among projects within ecoregions to assess treatment effectiveness on a larger scale and draw greater inferences regarding ES&R techniques. Determining which treatments are effective will enable the BLM to fund only those activities that are proven to work, thus saving the BLM money and increasing efficiency.

A monitoring program where comparable and statistically valid data are collected on many ES&R projects could be used to assist in answering multiple questions regarding treatment effectiveness. For instance, a database containing multiple ES&R project results could be produced with standardized monitoring data. This database would help to answer questions regarding what species to use (native or introduced) on a particular ecological site, the best time to seed a particular seedmix, and which specific seedbed preparation treatments are most effective., Additional questions could be answered by querying the database for specific data of interest. Such a tool would allow monitoring data to be collected that would not only fit into the adaptive management cycle, but also answer important questions regarding the overall effectiveness of specific ES&R treatments by functioning as a reliable storehouse of monitoring data.

While manuals and agency personnel have expressed concern with standardizing protocols, it is apparent that the majority of projects use the same basic techniques for vegetation monitoring throughout the USDA and USDI. Because the ES&R and BAER programs have specific objectives such as preventing the invasion or expansion of exotic species and increasing cover of perennial species to reduce soil erosion, standard protocols to address these limited objectives by ecoregion can be used. Some flexibility can be built into standard techniques to account for lesser or greater than normal variation such as changing quadrat sizes, transect lengths, and/or sample size. As long as sample adequacy is achieved, these changes will result in comparable data.

A quantitative approach which consists of a standard monitoring strategy and techniques that are designed to specifically address ES&R objectives by ecoregion would allow the BLM to determine overall treatment effectiveness. This approach would consist of the following: First, a standard method of stratifying monitoring units to facilitate comparison between projects. Second, an adequate amount of sampling locations are located randomly within each monitoring unit. Third, standard techniques would be used to measure vegetation attributes and erosion and ultimately assess treatment goals.

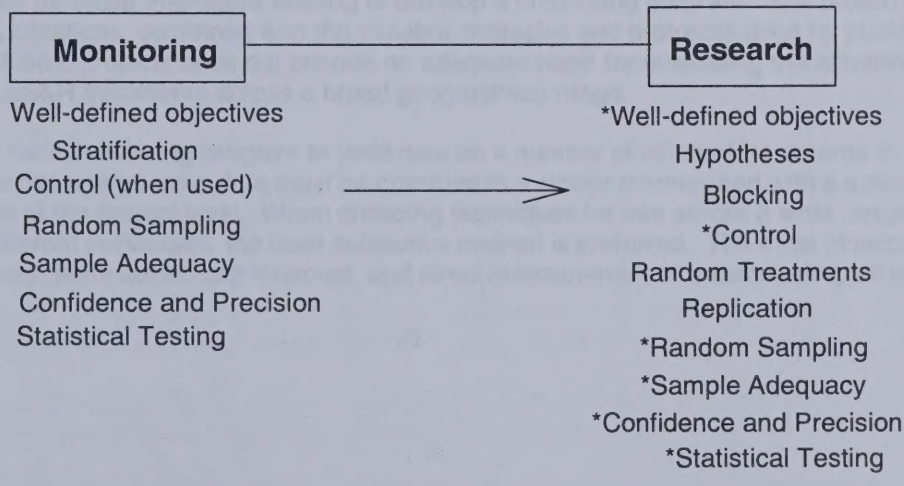
Five of the six primary sampling techniques described in the Monitoring Manual for Grassland, Shrubland, and Savannah, should be able address all basic ES&R vegetation monitoring objectives. These techniques are: photopoints, line point intercept, density belts/quadrats, and basal gap intercept. These techniques were specifically designed to monitor rangeland health but provide information directly related to ES&R objectives and treatment efficacy. Photopoints will be used to document the general conditions at the site. Line point intercept will provide information on cover of perennial vegetation, invasive species, and soil surface conditions which can be directly related to soil-vegetation resources and watershed stability objectives of most ES&R projects. Density measures establishment of seeded species and can be used to assess treatment success and change over time. Basal gap intercept and the soil stability test is used to measure the susceptibility of the site to water erosion. In addition, erosion monitoring using silt fences can be used to measure actual sediment loss where needed.

Many of the criticisms for a standard monitoring protocol were listed in Elzinga et al. 1998 and can be addressed using the proposed approach. One of the main criticisms is that monitoring data collected using standardized techniques are not designed for all issues, and therefore lack the ability to answer specific questions. The recommended approach is designed to answer the range of objectives that are common to most ES&R projects. In addition, since the methodologies are tied directly to ES&R objectives, and stratification and sample adequacy will be employed, the approach should have the power to detect change or threshold objectives, ensuring statistically defensible data. Thus, the methods can be standardized at the ecoregion scale.

Another criticism is that limited resources are available for monitoring projects and that projects need to be designed case by case to be as efficient as possible. We believe that by using this approach the design will be efficient and questions regarding the ability of a treatment to meet ES&R objectives can be determined. Once estimates of the time required to implement this monitoring approach are determined, the appropriate level of funding can be requested from the ES&R program when a monitoring plan is developed. If adequate personnel are not available to implement the monitoring project, contractors could be used to perform the monitoring after completing a certified training course.

Another common criticism of statistical monitoring approaches such as this one is that monitoring is not research, however, elements commonly used in research have been used to improve monitoring programs and are advocated by land management personnel and agency monitoring manuals. There are many similarities between an effective monitoring program and research. Factors that should be included in a monitoring program are 1) well-defined objectives and procedures, 2) stratification (similar to blocking), 3) controls and reference areas, 4) random sampling, 5) sample adequacy, 6) knowledge of the confidence, power, and precision obtained, and 7) statistical testing.

Figure 1. Similarities between monitoring and research.



Well-defined objectives in a monitoring program perform two functions. First, they establish a standard by which to measure success or failure and second, they determine what variables must be measured in order to assess whether the objectives are being met. Protocols used to measure each variable can be established so that data are collected consistently to facilitate comparisons. Well-defined protocols used by trained and knowledgeable personnel will also increase data quality.

Stratification is the partitioning of samples into defined monitoring units to reduce variation and increase precision. Stratification can be accomplished by delineating areas that may respond differently to ES&R treatments such as by soil type or ecological site. When burned areas are

stratified similarly in different projects then data can be more readily compared. Furthermore, adding control plots will allow a determination of what would happen without treatment. This is essential for assessing whether treatments were necessary, but may not be essential if objectives are well defined and do not require comparison to a reference area (e.g. target plant density).

As with research, random sampling in monitoring programs ensures that data are as unbiased and representative of the monitoring unit as possible. While this may be time consuming, random sampling is essential for defensible monitoring data. Monitoring data that is not collected using random sampling is open to criticism. Criticisms can be made that the data only came from areas where the treatments were effective, or that the data was biased in some other way and therefore unreliable.

Sample adequacy is relatively easy to obtain in communities that are uniform, and difficult to achieve in communities that are highly variable. Sample adequacy allows data to be collected within a known percentage of the sample mean (precision). This promotes confidence in the collected data and facilitates comparisons among other sites. Information about confidence, power, and precision can also be derived from sample adequacy data. Data that are good enough to perform statistical tests will give answers to questions regarding ES&R treatment effectiveness that are unbiased and defensible.

7. CONCLUSIONS

There is much disagreement on the use of a standard monitoring protocol or protocols. It is true that any one monitoring protocol will not work everywhere, however, a standard protocol by ecoregion, to answer basic ES&R program objectives would enable wider comparisons of treatment effectiveness. Different techniques could be used in shrublands than are used in forested lands. Techniques could be modified or new methods developed to accommodate new objectives.

The current technical references produced by the numerous federal agencies are excellent resources for those managers wishing to develop a monitoring program. The broad nature of these publications, combined with the variable strategies and protocols used for monitoring current ES&R projects does not provide an adequate basis for evaluating the effectiveness of various ES&R treatments across a broad geographical range.

In order for a monitoring program to yield data on a number of different treatments in different soil types across a large area data must be collected in a similar manner and with a specified level of precision at the project level. When choosing techniques for use across a wide range of areas by many different individuals, the least subjective method is preferred. The most objective methods are density, point cover, gap intercept, and direct measurement of erosion using silt fences.

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Table A-1. Advantages and disadvantages of measuring the three basic vegetation attributes			
	Cover	**Density**	**Frequency**
Description	The percentage of ground covered by vegetation (various definitions)	Density is the number of individuals per unit area.	Number of times a species is present in a given number of quadrats of a particular size. Expressed as a percentage.
Strengths	Equalizes the species that are small but abundant and the ones that are large but few, not biased by size or distribution of individuals. Most directly associated attribute to biomass. A good measure of the influence of the species in the community. Can be used for all life history types. Sensitive to changes in numbers or size of individuals. Related to site stability.	Because result is reported as individuals per unit area, results can be compared across sites even if different quadrat sizes were used (not true for frequency). Most sensitive to changes caused by mortality or recruitment. Density measurements are highly repeatable.	Can overcome some problems by using nested plots. If the plot is reduced to a point, then both cover and frequency of a species can be calculated. Highly repeatable. Simple to perform. Highly sensitive to changes in the distribution and/or density of key species or weed infestations. Can be used for all life history types.
Limitations	Must be very specific as to what type of cover is being measured (vegetation, crown, ground, basal, canopy). Can change dramatically over the course of the season or between years. Basal cover is less sensitive to climatic variation. Cannot determine whether change is due to decrease in size or decrease in individuals. Difficult to compare between sites as each site may have a different potential. Growth form of plant may influence cover measurements.	Must control for boundary errors/decisions. Will not detect changes in vigor (cover) or plant health. Seedlings must be recorded separately from mature plants. May be cumbersome if densities are extremely high. Cannot be used for all life history types (e.g. rhizomatous species with no consistent or meaningful counting unit).	Size and shape of plots influence results. Data collected with different plot sizes cannot be compared. Highly sensitive to large seedling establishment events. Frequency can change if spatial pattern of community changes even if the same number of plants are present. Also, if change in frequency is noted, whether the change is from canopy cover or density cannot be determined. Rooted frequency is less sensitive to change than canopy frequency.
Comments	Canopy cover, basal cover, ground cover can all be measured at the same time using the point intercept method.	Must Define counting unit. Errors can occur when there are cryptic or numerous individuals. A minimum search time per quadrat should be established to minimize errors from high-speed counting.	Must have a frequency in between 30 and 70% (20-80) in order to detect change in both directions. BLM 1730-1 suggests that frequency data should not be the only type of data collected.

Table compiled using the following manuals: BLM 1730-1, BLM 1734-4, Fire Monitoring Handbook, Fire Effects Monitoring and Inventory Protocol, Land Condition Trend Analysis II, and the Fuel and Fire Effects Monitoring Guide.

Table A-2. Advantages and disadvantages of three different methods of estimating cover

	Line Intercept	Point Intercept	Visual Estimation
Description	The distance along a tape measure that is intersected by a plant species or life form is recorded. The total length of the intersection is then used to calculate percent cover. Designed to sample plant species with dense crowns or large basal areas. Can sample canopy or basal cover, vegetation or gap.	A thin sampling pin is lowered at regular intervals along a transect. Each contact with the pin is recorded including multiple canopy layers and substrate. Designed to detect change in plant species cover for grasses, shrubs, and forbs that are less than 3 feet tall.	A quadrat is used to visually estimate cover for each species/life form/substrate using classes. The midpoint of each cover class is used to calculate mean cover for each variable of interest.
Strengths	Works well on shrubs over 3 feet tall with generally well defined boundaries, mat-forming plants, and basal areas.	Considered one of the most objective ways to measure cover. Works well for fine textured herbaceous communities. Multiple layers can be sampled including substrate which is correlated with soil stability. Basal cover can also be estimated which is less sensitive to environmental Highly repeatable. More efficient than quadrat and line intercept methods for measuring cover.	Able to sample more area than line or point intercept.
Limitations	Not well suited for single stemmed plants or dense grasslands. Canopy gaps less than 15 cm are generally ignored possibly leading to overestimation.	It is difficult to detect rare plants with this method. Errors can occur from the movement of plants by wind. Pins are generally better than rods because of the smaller diameter. A point intercept with too large of a diameter will overestimate cover. Grouped points such as in point frames are generally less efficient than individual points along a transect. May not work for taller vegetation types Observer bias can be introduced if points are placed manually.	More subjective. Extensive calibration of observers required. This does not allow for the easy change of quadrat size in response to community type. Unknown level of observer bias. Variability is different depending on life form or species. Not sensitive to small changes in cover. Can be time consuming if the cover of all species are estimated.
Comments	Gap intercept is very similar to this except measures area not covered by vegetation.	Plants over 1.5 m can be sampled using an optical sighting device.	This is considered a semi-quantitative method by Bonham (1989).

Table compiled using the following manuals: BLM 1730-1, BLM 1734-4, Fire Monitoring Handbook, Fire Effects Monitoring and Inventory Protocol, Land Condition Trend Analysis II, and the Fuel and Fire Effects Monitoring Guide.